

Evaluation of the development of competences in radiology and diagnostic imaging in a cross-sectional study in a medical graduation

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Abstract— To assess the development of skills by medical students in radiology and diagnostic imaging in a cross-sectional way in undergraduate medicine in an integrated and interdisciplinary curriculum. This is a quantitative, analytical, and expository cross-sectional study, through the application of a structured questionnaire on the radiological themes developed in the axis that has as practical support the Morfofunctional Laboratory, with students from the 1st, 5th and 8th semester of the medical course at the Centro Universitário Metropolitano da Amazônia (UNIFAMAZ), Belém, PA – Brazil. For the

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elaboration of the result of the present study, the analysis of 93 applied questionnaires was used, respecting the selection criterion, in which the questionnaire should contain the Free and Informed Consent Term duly completed and signed, of which 15 already had a previous graduation. The students at each end of the application of the questionnaire were more confident during the semesters, represented by the increasing average of correct answers over the semesters, and, in this way, corroborating the evolution of the students in the resolution and reasoning of the proposed questions. The information obtained from the medical students evaluated in the study corroborate that problem-based learning facilitates and assists in the process of obtaining knowledge, through the morphofunctional components of the course used to approach radiology and diagnostic imaging with a view multidimensional in addition to the role of complementary examination methods.

I. INTRODUCTION

Radiology is a medical specialty that renews itself and advances every day, in a modernization process that, in addition to investments, requires continuous effort to update. Intrinsically linked to technological development, diagnostic imaging methods allow physicians to obtain information that could not have been imagined less than ten years ago, with a speed and efficiency that enhance Medicine as a whole. (Scatigno Neto, 2019).

It plays an important role in modern medicine, since imaging technologies have revolutionized the clinical practice of medicine in Brazil and worldwide, (Corr P, 2012), but many of the students are not properly prepared for the discipline during the early years of college or are presented with the discipline in a non-transversal way, a set of general personal skills that are useful and important in the context of the performance of different activities, interdisciplinary. (Branstetter BF et al., 2007).

The use of radiological images is a fundamental part of learning due to their availability and undeniable clinical relevance. Some studies indicate that the “early” insertion of this skill enriches the understanding of pathophysiological processes, as well as anatomy. This is due to rapid technological advances, the availability and use of alternative resources for teaching anatomy and clinical correlation (Kalami TR et al., 2016).

Since the advent of imaging tests, radiology and diagnostic imaging have made important advances in several areas. Therefore, it is essential that there are trained professionals to know the techniques and the appropriate use of these complementary exams (Corr P, 2012), since their inappropriate use implies damage both for the patient and for the health system (Silva et al., 2019).

Consequently, preparing medical students to become responsible users of medical images, including, for this purpose, the teaching of radiology and diagnostic imaging in the undergraduate medical curriculum, is the target of increasing attention (Lim-Dunham, 2016).

The National Curriculum Guidelines (NCGs) for the Undergraduate Medicine Course (Brasil, 2014) define the organization, development and evaluation of the course, within the scope of the higher education system in the country, and guide the promotion of integration and interdisciplinarity in coherence with the curriculum development axis, and the use of methodologies that privilege the active participation of the student in the construction of knowledge.

In this sense, some doubts emerged related to the model, the content and the ideal period to introduce the learning of radiology and imaging diagnosis, showing the need to develop an effective means for teaching this (Silva et al., 2019).

Al Qahtani et al (2014), points out that at the Al-Baha University Faculty of Medicine (ABUFM), in Al-Baha - Saudi Arabia – it should have been during the initial stages of curriculum development and these issues arose. Alternatives to answer this question were to approach radiology within other clinical disciplines through an “when indicated” approach, to allocate a distinct and specialized module or to integrate a related theme longitudinally into the curriculum during its 6 academic years (Al Qahtani et al, 2014).

The teaching of radiology and diagnostic imaging began to integrate the Axis Of Health Care and Education (AES), in the morphofunctional laboratory (LMF) (FAMAZ, 2017), developed in some periods, with active methodologies and favoring the teaching method in vertically integrated stages. The assimilation of content

through this means allows a lasting learning, relevant in the practical and real clinical work of the students (Lim-Dunham, 2016).

The evaluation of the development of competencies by the medical student in radiology and imaging diagnosis in a transversal way in the undergraduate course in medicine in an integrated and interdisciplinary curriculum, using active methodology, is significant for the training of the medical professional.

II. METHOD

The present study was carried out at the Metropolitan University Center of the Amazon (UNIFAMAZ), Belém, PA – Brazil, with students from the 1st, 5th and 8th semester of the medical course, between December 2021 and April 2022. This is a quantitative, analytical and expositive cross-sectional study. The inclusion criteria were: to be a student regularly enrolled in the medical course of the university center mentioned above, to be frequent in the curricular activities of the 1st, 5th or 8th semester of the course and to agree to participate in the study by signing the Free and Informed Consent Form proposed in the questionnaire applied.

The material proposed for the study was a structured questionnaire containing radiology and diagnostic imaging themes in the Morphofunctional Laboratory of the Metropolitan University Center of the Amazon, based on the curriculum for the teaching of radiology of the University Center, which lists the minimum contents for learning in each semester of medical graduation.

UNIFAMAZ presents in the medical course thematic axes subdivided into curricular units. In the Health Care and Education (AES) axis, one of the methodologies applied is Problem Based Learning (FAMAZ, 2017). For the development of the axis, practical support and an anatomical, physiological, histopathological and radiological basis, among others, are provided by the Morfofuncional Laboratory.

Considering that the semester to be attended by the student is a modifying factor of the degree of difficulty in answering the questions in the questionnaire and bearing in mind that the subject may not yet have been the subject of the interviewee's semester. Thus, the questionnaire was subdivided into the following subjects: Identification of the types of exams and their characteristics, Human anatomy in radiology, human pathology in radiology and diagnostic imaging.

The questionnaire had multiple-choice questions, with four items in each question, with only one of the alternatives being considered correct according to what is delimited by

the Brazilian Society of Radiology and Imaging Diagnosis and content worked in the institution.

In addition, another factor analyzed was the possibility of some previous training to verify if there was a difference that favored the completion of the questions presented. The research was developed in person without prior notice to the students that there would be the evaluation, but with authorization of the application by the institution and the teachers, at the end of the classes of the class to be addressed, using the list of regularly enrolled students who were approached to fill out the questionnaire and agreed to participate in the study.

The questionnaire was answered at the same time as delivery and returned immediately to the researchers after completion of the resolution. During the completion of the questionnaire, participants were not allowed to clarify doubts, consult books and other students and have access to the internet, cell phone or any electronic devices. Data were computed exclusively from participants who correctly completed and signed the Free and Informed Consent Form.

After data was used, after collection, the separation was performed by means of tables and spreadsheets, organizing them into three large groups indicating each semester evaluated, with the respective correct answers and general and individual errors of the participants, through analysis of the quantitative variables described through their absolute value, frequency distribution and occurrence rate. Subsequently, each group was subdivided into the individual characteristics of each question, as mentioned in the fourth paragraph of this item, in order to generate graphs that more easily show the research objectives.

Data were analyzed using Microsoft Excel using tables, graphs and numerical summary, which provided a demonstration of the collected data. Quantitative variables were described by means of their absolute value, frequency distribution and occurrence rate. For the methodological analysis of this article, as proposed by Yin, R.K. (2015), a methodological design is presented to understand the nature of a contemporary and social phenomenon applied in its context in the classroom, making the analysis more objective, over which the researchers had no control over what they want to clarify.

The research project followed the legal precepts recommended by Resolution 196 of the National Health Committee of Brazil - CNS-CONEP. The research was observed by the UNIFAMAZ Ethics Committee, upon submission to Pataforma Brasil, due to the need to use data collected from human beings in the research.

III. RESULTS AND DISCUSSION

The analysis of 93 applied questionnaires were used to elaborate the result of the present study, respecting the selection criterion, in which the questionnaire should contain the Free and Informed Consent Form duly completed and signed, distributed as shown in figure 1. There were no students who opposed participating in the research.

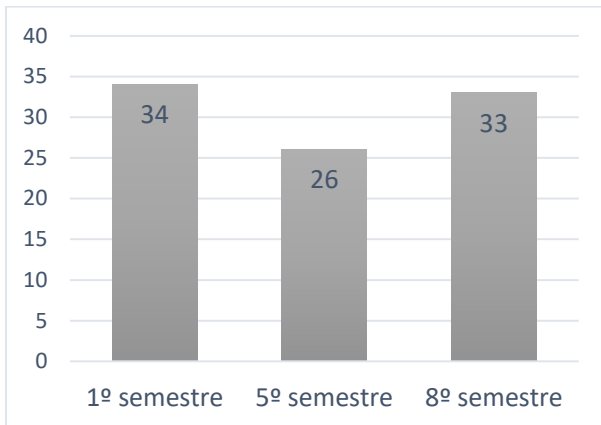


Fig.1. Distribution of students by semester.

Source: Own authorship. Belém (PA), Brasil, 2023.

The interviewees were asked about having completed some specialization before starting graduation. Therefore, among the 93 interviewees, 15 already had a previous graduation, which represent about 16% of the total. There were three specialists present among the academics of the 1st semester. Such data are then detailed as shown in table 1.

Table 1. Distribution of graduate students by specialty.

Previous graduation	1st semester	5th semester	8th semester
Nursing	0	2	0
Physiotherapy	0	0	1
Hospital Management	0	0	1
Biomedicine	0	0	1
Nutrition	0	0	2
Odontology	1	1	1
Biology	1	0	1
Electrical Engineering	1	0	0
Administration	0	1	0
Production engineering	0	1	0

Source: Own authorship. Belém (PA), Brasil, 2023.

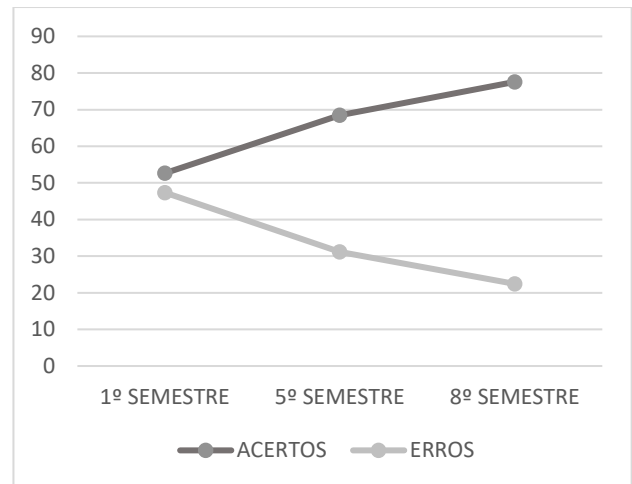


Fig.2. Distribution of students by semester.

Source: Own authorship. Belém (PA), Brasil, 2023.

Regarding the thematic axes presented, there was also a progressive increase as the semester progressed. The themes “Identification of the types of exams and their characteristics”, “Radiological anatomy”, “Radiology and diagnostic imaging” were renamed in figure 3 as Themes 1, 2 and 3 respectively, as well as presenting the correct rate in each one. of the topics addressed, presented both in the form of absolute and relative frequency of correct answers. Subsequently, the questions were grouped in table 2 containing the four questions related to theme 1, which represent the 1st, 2nd, 3rd, and 5th questions, three sentences related to theme 2, which include the 4th, 7th, and 9th questions and three sentences on theme 3, which correspond to the 6th, 8th and 10th, thus totaling the ten questions available in the survey.

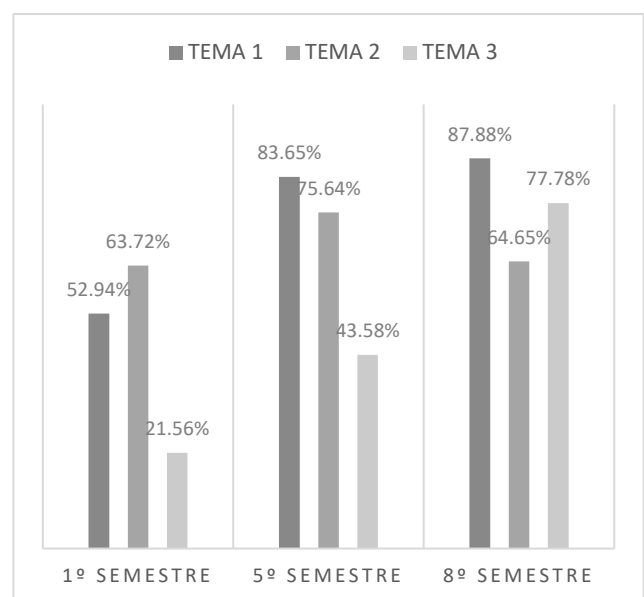


Fig.3. Hit rate of respondents by thematic axis.

Source: Own authorship. Belém (PA), Brasil, 2023.

Table 2. Rate of correctness of respondents in each question.

Questions	1st Semester		5th Semester		8th Semester	
	Absolute Frequency	Relative Frequency	Absolute Frequency	Relative Frequency	Absolute Frequency	Relative Frequency
1st	15	44,12%	18	69,23%	28	84,85%
2nd	18	52,94%	23	88,46%	23	69,70%
3rd	33	97,05%	26	100%	33	100%
4th	25	73,53%	22	84,61%	21	63,64%
5th	24	70,58%	20	76,92%	32	96,97%
6th	10	29,41%	4	15,38%	28	84,85%
7th	22	64,70%	24	92,30%	33	100%
8th	6	17,64%	14	53,84%	16	48,49%
9th	18	52,94%	13	50%	10	30,30%
10th	6	17,64%	16	61,53%	33	100%

Source: Own authorship. Belém (PA), Brasil, 2023.

In view of the completed questionnaires, the characteristics of the studied population are observed, consisting of 93 medical students, with samples being collected from the 1st, 5th and 8th year of the UNIFAMAZ, of which 34 belonged to the 1st year, 26 to the 5th year and 33 made up the class of the 8th semester of the Medical Course that use PBL as one of the study methodologies for the Morphofunctional axis that addresses imaging based on self-directed learning (Trullàs JC, et al., 2022).

In addition, among the total number of students interviewed in the survey, 15 already had a previous degree, which represent about 16% of the total and demonstrated a certain maturity when answering the proposed questionnaire, with reports that they had already studied or experienced some of the questions previously, either in training or professional performance, as well as, in daily life, through experience. Therefore, among the 10 specialists in health-related areas presented among the participants, such as nurse, dentist, physiotherapist, biomedical, nutritionist and hospital manager, only three were below the average for the semester they had attended, a value equivalent to 30% of undergraduate students in the health area, compared to 46.98% of the students who had not attended a previous specialization or attended but were not related to health.

Students at each end of the questionnaire application were more confident over the semesters, represented by the growing average of correct answers over the semesters, and thus corroborating the students' evolution in solving and reasoning the proposed questions. Thus, the need for early

introduction of radiology into the curricular component of morphofunctional is evident in the students' responses by increasing as the semester increases to be attended, thus, this serves as a support to recognize that the introduction of basic concepts of radiology in a transversal way in the thematic modules, make it possible to relate knowledge of the basic sciences, such as anatomy with basic and advanced concepts of imaging (Foltran et al., 2015).

In view of this, a meta-analysis was carried out which showed that the PBL teaching method had a positive effect in obtaining higher theoretical scores compared to the traditional teaching method in 16 studies. As well, thirteen studies provided sufficient data on skill scores, and a significant difference in favor of PBL was also observed. Questionnaire surveys were applied in most of the included studies and indicated positive effects of PBL on students' learning interest, scope of knowledge, team spirit and oral expression in radiology teaching (Zhang S, et al., 2018).

In line with early study adherence and radiology teaching methodology, Berger et al., 2019 compares the PBL study used in cardiopulmonary resuscitation (CPR) learning combined with high-fidelity simulation training leads to an increase in measurable short- and long-term learning at the beginning of sufficient CPR by medical students after training compared to classical education compared to classical education. As in the study by Rocha BC et al., (2021) demonstrated that the methodologies (traditional, hybrid, e-learning and problem-based learning) tested had similar performance; however, the traditional

methodology showed less acceptance by students when analyzed subjectively and comparatively.

Regarding the questionnaire, there was a variation in the correctness rates, in general, the first semester students were the ones with the lowest performance in all the thematic axes addressed in the questionnaire. In view of this, we highlight the evaluation of the third group of questions related to more advanced concepts of imaging, such as imaging diagnosis through pathological changes associated with the students of the first semester, which presented more difficulties, by observing the percentage of correct answers, with about 21.56%.

The question that showed the best domain of the interviewees was the 3rd question, having the highest percentages of correct answers from the participants in all semesters, 100% of correct answers in the 5th and 8th semesters and 97.05% in the first semester. Students in the third question should identify the alternative that was showing a chest X-ray, with the other alternatives being computed tomography, ultrasound and magnetic resonance imaging, all showing a chest image.

It is also worth paying attention to the question that presented a great variation in the correctness rate of the interviewees: The 10th question. The percentage of correct answers for students in the first semester was 17.64%; 61.53% in the fifth and 100% in the eighth semester, which may be a reflection of the impact of a contextualized question in the individual analysis of each participant. In this question, a clinical picture of a patient with changes in the menstrual cycle was presented, associated with an ultrasound image of the uterine region with an image suggestive of uterine myoma, with endometriosis, endometrial neoplasia and cervical neoplasia as other alternatives (Silva et al., 2019).

Teaching in the basic and clinical cycle of a medical course, from the 1st to the 4th year, is a period to acquire the knowledge of the subjects in the basic area necessary for the application during the period of the boarding school, from the 5th to the 6th year, whose objective is to prepare the student, providing him with security, knowledge and experience to obtain sufficient theoretical basis to solve the most frequent and recent problems in the professional environment. Therefore, the study by Matlala S. (2021) addresses issues such as tuberculosis, human immunodeficiency virus and acquired immunodeficiency syndrome (HIV and AIDS) and, more recently, the pandemic of coronavirus disease 2019 (COVID-19), in addition to the advancement of technology and the change of regulations and policies, demonstrating the effectiveness of teaching-learning also from the point of view of teachers.

Thus, much of the basic and clinical cycle occurs within the HEI with the objective of the students knowing not only the semiotecnic in health environments, but also having the theoretical support necessary for the construction of a quick clinical reasoning, an efficient request and interpretation of complementary exams and a correct conduct as a future physician (Al Qahtani et al., 2014).

IV. CONCLUSION

The information obtained from the medical students evaluated in the study corroborate that problem-based learning facilitates and helps in the process of obtaining knowledge, through the morphofunctional components of the course used to approach radiology and imaging diagnosis with a multidimensional view beyond the role of complementary examination methods.

Along with this, other knowledge, particularly anatomy and pathology, facilitate the study of radiology because they contextualize clinical situations in the way that would possibly be addressed if the student was in a similar situation professionally, so the means of complementary diagnosis should be approached multidimensionally from the beginning of the medical course until their training.

Diagnostic accuracy in radiology is a skill to be developed progressively between medical students and the graduate professional, but the mastery of technical vocabulary for understanding the reports of the requested tests, as well as the due use of diagnostic imaging mechanisms are fundamental points to medical education. Associated with this, teaching using the PBL proves to be an effective and satisfactory methodology for medical education, allowing medical students to acquire not only knowledge, but also other skills necessary for medical professionalism. (Trullàs JC, et al., 2022).

Through the significant informational and technological advances that allow exploring various anatomical, histological, physiological and pathological aspects, and due to the easy archiving of digitized images, allowing the formation of large collections, the proposal to use radiology as a learning tool since the beginning of the course is positive. Therefore, over time, it is avoided that many future physicians do not have real conditions to interpret tests and perform appropriate conducts, in addition to dealing with possible problems to which they are exposed (Branstetter IV et al., 2007).

REFERENCES

- [1] Al Qahtani, F., & Abdelaziz, A. (2014). Integrating radiology vertically into an undergraduate medical education curriculum: a triphasic integration approach. *Advances in*

- medical education and practice, 5, 185–189. <https://doi.org/10.2147/AMEP.S58858>.
- [2] Brasil. (2014). Ministério da Educação (MEC). Diretrizes Curriculares Nacionais. http://portal.mec.gov.br/index.php?option=com_docman&view=download&alias=15874-rces003-14&category_slug=junho-2014-pdf&Itemid=30192.
- [3] Branstetter, B. F., 4th, Faix, L. E., Humphrey, A. L., & Schumann, J. B. (2007). Preclinical medical student training in radiology: the effect of early exposure. *AJR. American journal of roentgenology*, 188(1), W9–W14. <https://doi.org/10.2214/AJR.05.2139>.
- [4] Yin, R.K. (2015) Estudo de caso. Planejamento e métodos. Tradução de Daniel Grassi. 5ed. Porto Alegre (RS): Bookman. 290 p.
- [5] Corr, P. (2012). Using e-learning movies to teach radiology to students. *Med Educ*. 46:1119–112. “Autores, coloquem em itálico o nome da revista "Med Educ.". Ex. incorreto: “5. Farias, P. A. M., Martin, A. L. de A. R., & Cristo, C. S. (2015). Aprendizagem Ativa na Educação em Saúde: Percorso Histórico e Aplicações. *Revista Brasileira de Educação Médica* [online]. v. 39, n. 1 [Acessado 6 novembro 2021], pp. 143-150. ISSN 1981-5271. <https://doi.org/10.1590/1981-52712015v39n1e00602014>.
- [6] Farias, P. A. M., Martin, A. L. de A. R., & Cristo, C. S. (2015). Aprendizagem Ativa na Educação em Saúde: Percorso Histórico e Aplicações. *Revista Brasileira de Educação Médica* [online]. v. 39, n. 1 [Acessado 6 novembro 2021], pp. 143-150. ISSN 1981-5271. <https://doi.org/10.1590/1981-52712015v39n1e00602014>.
- [7] Foltran, C., Pizzol, L. R., Santana, M. L. G. C. de, & Fernandes, M. R. (2015). Avaliação do conhecimento na requisição correta dos exames de imagem dos internos de 5o e 6o ano da Faculdade de Medicina da Universidade de Mogi das Cruzes, SP. *Revista De Medicina*, 94(2), 126-134. <https://doi.org/10.11606/issn.1679-9836.v94i2p126-134>.
- [8] Lim-Dunham, J. E., Ensminger, D. C., McNulty, J. A., Hoyt, A. E., & Chandrasekhar, A. J. (2016). A Vertically Integrated Online Radiology Curriculum Developed as a Cognitive Apprenticeship: Impact on Student Performance and Learning. *Academic radiology*, 23(2), 252–261. <https://doi.org/10.1016/j.acra.2015.09.018>.
- [9] Burgess, A., Matar, E., Roberts, C., Haq, I., Wynter, L., Singer, J., Kalman, E., & Bleasel, J. (2021). Scaffolding medical student knowledge and skills: team-based learning (TBL) and case-based learning (CBL). *BMC medical education*, 21(1), 238. <https://doi.org/10.1186/s12909-021-02638-3>.
- [10] Faculdade Metropolitana da Amazônia - FAMAZ (2017). Grupo Educacional CEUMA. Projeto Pedagógico de Curso: Curso de Bacharelado em Medicina. <http://www.famaz.edu.br/portal/wp-content/uploads/2017/11/PPC-Medicina.pdf>.
- [11] Scatigno Neto, A. (2005). A Radiologia, o Radiologista e as demais especialidades. *Radiologia Brasileira* [online]. v. 38, n. 2 [Acessado 12 novembro 2021], pp. III. Disponível em: <<https://doi.org/10.1590/S0100-39842005000200001>>.
- Epub 24 Maio 2005. ISSN 1678-7099. <https://doi.org/10.1590/S0100-39842005000200001>.
- [12] Silva, A. F. da et al (2019). Percepção do Estudante de Medicina sobre a Inserção da Radiologia no Ensino de Graduação com Uso de Metodologias Ativas. *Rev. bras. educ. méd.*, v. 43, n. 2, p. 95-105. <https://doi.org/10.1590/1981-52712015v43n2RB20180126>.
- [13] Berger, C., Brinkrolf, P., Ertmer, C., Becker, J., Friederichs, H., Wenk, M., Van Aken, H., & Hahnenkamp, K. (2019). Combination of problem-based learning with high-fidelity simulation in CPR training improves short and long-term CPR skills: a randomised single blinded trial. *BMC medical education*, 19(1), 180. <https://doi.org/10.1186/s12909-019-1626-7>.
- [14] Zhang, S., Xu, J., Wang, H., Zhang, D., Zhang, Q., & Zou, L. (2018). Effects of problem-based learning in Chinese radiology education: A systematic review and meta-analysis. *Medicine*, 97(9), e0069. <https://doi.org/10.1097/MD.00000000000010069>.
- [15] Subramaniam, R. M., Scally, P., & Gibson, R. (2004). Problem-based learning and medical student radiology teaching. *Australasian radiology*, 48(3), 335–338. <https://doi.org/10.1111/j.0004-8461.2004.01317.x>.
- [16] Liu, C. X., Ouyang, W. W., Wang, X. W., Chen, D., & Jiang, Z. L. (2020). Comparing hybrid problem-based and lecture learning (PBL + LBL) with LBL pedagogy on clinical curriculum learning for medical students in China: a meta-analysis of randomized controlled trials. *Medicine*, 99(16), e19687. <https://doi.org/10.1097/MD.00000000000019687>.
- [17] Trullàs, J. C., Blay, C., Sarri, E., & Pujol, R. (2022). Effectiveness of problem-based learning methodology in undergraduate medical education: a scoping review. *BMC medical education*, 22(1), 104. <https://doi.org/10.1186/s12909-022-03154-8>.
- [18] Matlala S. (2021). Educators' perceptions and views of problem-based learning through simulation. *Curationis*, 44(1), e1–e7. <https://doi.org/10.4102/curationis.v44i1.2094>.
- [19] Luke, A. M., Mathew, S., Kuriadom, S. T., George, J. M., Karobari, M. I., Marya, A., & Pawar, A. M. (2021). Effectiveness of Problem-Based Learning versus Traditional Teaching Methods in Improving Acquisition of Radiographic Interpretation Skills among Dental Students-A Systematic Review and Meta-Analysis. *BioMed research international*, 2021, 9630285. <https://doi.org/10.1155/2021/9630285>.
- [20] Rocha, B. C., Rosa, B. S. P., Cerqueira, T. S., de-Azevedo-Vaz, S. L., Barbosa, G. L. R., Ferreira, L. M., Verner, F. S., & Visconti, M. A. (2021). Evaluation of different teaching methods in the radiographic diagnosis of proximal carious lesions. *Dento maxillo facial radiology*, 50(4), 20200295. <https://doi.org/10.1259/dmfr.20200295>.